

This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.**

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11)

EP 1 223 717 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
17.07.2002 Bulletin 2002/29

(51) Int Cl.7: H04L 25/03

(21) Application number: 01300298.5

(22) Date of filing: 15.01.2001

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: LUCENT TECHNOLOGIES INC.
Murray Hill, New Jersey 07974-0636 (US)

(72) Inventors:
• Kopmeiners, Robert John
Hengelo, 3511 GH Overijssel (NL)
• van Nee, Didier Johannes Richard
3454 XR De Meern, N.A. (NL)

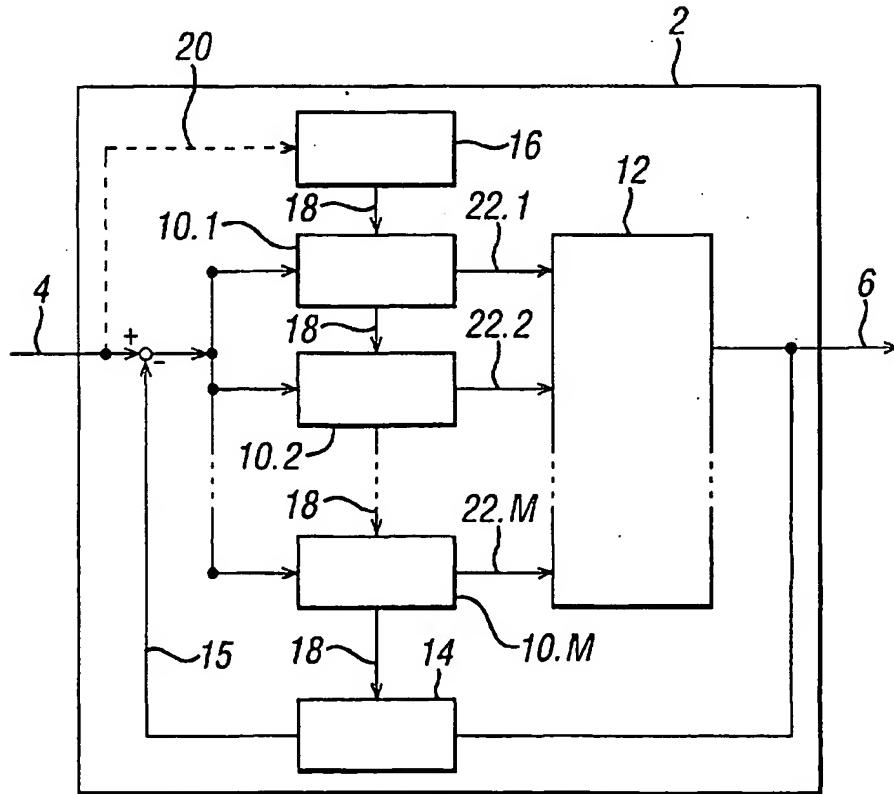
(74) Representative: Williams, David John et al
Page White & Farrer,
54 Doughty Street
London WC1N 2LS (GB)

(54) Maximum likelihood detection method using a sequence estimation receiver

(57) The invention relates to a detection method using a receiver of a digital communication system for the detection of a symbol from a received signal, which signal is transmitted by a transmitter of the digital commun-

ication system, wherein the symbol is a selected symbol out of a predetermined set of symbols and wherein each symbol of the predetermined set comprises a sequence of chips wherein each of the chips is PSK-modulated according to a selected modulation code.

FIG. 1



Description

[0001] The invention relates to a detection method using a receiver of a digital communication system for the detection of a symbol from a received signal, which signal is transmitted by a transmitter of the digital communication system, wherein the symbol is a selected symbol out of a predetermined set of symbols and wherein each symbol of the predetermined set comprises a sequence of chips wherein each of the chips is PSK-modulated according to a selected modulation code.

[0002] Detection methods of this kind are known and find their applications in a variety of digital data communication systems. These data communication systems can for instance be wireless data communication systems. According to known methods the receiver of the data communication system detects a symbol by detecting successively the chips of the symbol. This is referred to as chip-by-chip detection. After the detection of each chip a correction signal for the Inter Chip Interference (ICI-effect) between neighbouring chips is generated and subtracted from the received signal.

[0003] A first disadvantage of known methods is that detecting on chip-by-chip basis gives rise to some loss of coding gain with respect to detecting an entire symbol at one go (this is detecting on symbol-by-symbol basis). A second disadvantage of known methods is that no use is made of the a priori knowledge of the predetermined set.

[0004] It is an object of the invention to provide in a detection method which yields an optimal coding gain by detecting an entire symbol at one go. It is also an object of the invention to provide in a detection method which uses a priori knowledge of the predetermined set. For this, the detection method of the invention is characterised in that a set of reference symbols is generated on the basis of the predetermined set of symbols and the channel impulse response between the transmitter and the receiver, wherein each of the successive parts of the received signal, each part having the length of a symbol, is compared with each of the reference symbols, yielding a detected symbol for each part of the received signal. This detection method yields an optimal coding gain since complete symbols are detected at one go. Furthermore, a priori knowledge of the predetermined is used by only comparing the received signal with reference symbols corresponding to symbols from the predetermined set. The latter approach also saves processing power with respect to a detection method wherein all possible combinations of chips are compared with the received signal. A further advantage of the method according to the invention is that the ICI-effect is maximally suppressed. This is caused by the fact that the ICI-effect has been taken into account implicitly in the generation of reference symbols. These reference symbols are created by convolving the symbols out of the predetermined set with the channel impulse response between the transmitter and the receiv-

er.

[0005] A preferred embodiment of the method according to the invention is characterised in that a correction signal is generated on the basis of the detected symbol convolved with the channel impulse response, wherein the correction signal is subtracted from the part of received signal which succeeds the part of the received signal corresponding to the detected symbol for suppressing the ISI-effect. The ISI-effect may occur (in an analogous way as the ICI-effect) as a consequence of TDS. In the detection method of the invention each time a part of the received signal with the length of a symbol is corrected for the ISI-effect as soon as a symbol from the preceding part with the length of a symbol of the received signal is detected. The correction signal may be an estimated coefficient multiplied with the detected symbol convolved with the channel impulse response.

[0006] A further embodiment of the method according to the invention is characterised in that the comparison between each of the parts of the received signal with each of the reference symbols is performed by a correlator yielding a correlation value, wherein the correlation value is corrected with half the energy of the reference symbol.

[0007] An alternative embodiment of the detection method of the invention is characterised in that the received signal is filtered by a filter which yields a filter signal, wherein the filter is a matched filter to the channel impulse response between the transmitter and the receiver, wherein each of the successive parts of the filter signal, each part having the length of a symbol, is compared with each of the symbols from the predetermined set of symbols yielding a detected symbol for each part of the filter signal. In this embodiment the received signal is in a first step corrected for the channel impulse response between transmitter and receiver.

[0008] A further embodiment of the alternative detection method according to the invention is characterised in that a correction signal is generated on the basis of the detected symbol, wherein the correction signal is subtracted from the part of filter signal which succeeds the part of the filter signal corresponding to the detected symbol for suppressing the ISI-effect.

[0009] A still further embodiment of the alternative detection method according to the invention is characterised in that the comparison, between each of the parts of the filter signal with each of the reference symbols, is performed by a correlator yielding a correlation value, wherein the correlation value is corrected with half the energy of the reference symbol.

[0010] In the accompanying drawings, in which certain modes of carrying out the present invention are schematically shown for illustrative purposes:

Figure 1 is a diagram schematically showing a receiver for performing a detection method according to the invention;
 Figure 2 presents a symbol comprising eight chips,

wherein each chip is Phase Shift Keying Modulated; Figure 3 is a diagram schematically showing an alternative receiver for performing a detection method according to the invention.

[0011] A receiver 2 of a digital communication system for receiving a signal 4 and performing a detection, according to a detection method of the invention, of a symbol from the received signal 4 is shown in figure 1. The signal 4 is transmitted by a transmitter of the digital communication system to the receiver 2. The output 6 of the receiver 2 is the detected symbol from the received signal 4. The detected symbol is a selected symbol out of a predetermined set of symbols. Each symbol of the predetermined set comprises a sequence of chips wherein each of the chips is PSK-modulated according to a selected modulation code. An example of a symbol 8 of the predetermined set comprising eight chips C_1 up to and including C_8 is shown in figure 2.

[0012] The receiver 2 comprises a set of correlation blocks 10.1 up to and including 10.M for performing correlations between the received signal 4 and reference symbols from a set of reference symbols, a decision block 12 for selecting one of said reference symbols, a feedback block 14 for generating a correction signal 15 for suppressing the Inter Symbol Interference effect (ISI-effect) and an estimation block 16 for generating an estimation 18 of the channel impulse response between the transmitter and the receiver on the basis of a reference signal 20.

[0013] In a first step of the detection method of the receiver 2 the received signal 4 is correlated with symbols from a set of reference symbols. These correlations are performed by a set of M correlation blocks 10.m ($m=1, \dots, M$). In this example the m^{th} correlation block correlates the received signal 4 with the m^{th} reference symbol S_m from the set of M reference symbols. The correlations are performed between successive parts of the received signal 4 wherein each part has the length of a symbol. This yields M correlation values 22.m ($m=1, \dots, M$) per part of the received signal. Each of the correlation values may be corrected with half the energy of the corresponding reference symbol in order to make the correlation values mutually comparable. Next, these correlation values are the input to the decision block 12 which selects the reference symbol corresponding to the largest correlation value. The detected symbol is the symbol from the predetermined set of symbols which correspond with the selected reference symbol for the part of the received signal. The detected symbol is the output 6 of the receiver 2.

[0014] Time Delay Spread (TDS) is the effect wherein a received signal, which has been transmitted by a transmitter, has spread out in time with respect to the signal before transmission. This results in that a part of the signal may end up in another part of the received signal. The TDS-effect may occur as a result of multi-path in the channel between transmitter and receiver.

The Inter Chip Interference (ICI-effect) is the result of the TDS-effect wherein a chip smears out over a neighbouring chip. The Inter Symbol Interference (ISI-effect) is the result of the TDS-effect wherein a symbol smears out over a neighbouring symbol. The receiver 2, performing a detection method according to the invention, effectively suppresses the ICI-effect since entire symbols are detected at one go by comparing entire symbols with reference symbols (this is called detection on symbol-by-symbol basis). Since the reference symbols are convoluted with the channel impulse response the ICI-effect is automatically accounted for.

[0015] For the suppression of the ISI-effect in the detection method performed by the receiver 2 a feedback loop is used comprising the feedback block 14. The feedback block 14 calculates a correction signal 15 for the received signal 4. This correction signal 15 is a function of the detected symbol. This function may be an estimated coefficient multiplied with the detected symbol convolved with the channel impulse response between the transmitter and the receiver. The correction signal 15 is subtracted from the part of received signal which succeeds the part of the received signal corresponding to the detected symbol.

[0016] The M reference symbols S_m ($m=1, \dots, M$) are obtained by convoluting the symbols from the predetermined set with the channel impulse response between the transmitter and the receiver. This implicates that the symbols from the set of reference symbols have to be re-calculated regularly and at least every time when the channel impulse response has changed. The estimation 18 of the channel impulse response is performed by the estimation block 16 on the basis of the reference signal 20. The estimation 18 is fed to the correlation blocks 10.m ($m=1, \dots, M$). Then, the m^{th} correlation block calculates the reference symbol S_m ($m=1, \dots, M$) which is used for correlations to be performed by the m^{th} correlator.

[0017] An alternative receiver 24 of a digital communication system for receiving a signal 4 and performing a detection method according to the invention of a symbol from the received signal 4 is shown in figure 3. The signal 4 is transmitted by a transmitter of the digital communication system to the receiver 24. The output 6 of the receiver 24 is the detected symbol from the received signal 4. The receiver 24 comprises a matched filter 26 on the channel between the transmitter and the receiver, a correlator-bank 28 comprising a set of correlators, an correction block 30 for generating correction terms 31 for the output of the correlator-bank 28, a decision block 32 for selecting a detected symbol from the predetermined set of symbols and a feedback-block 34 for generating a correction signal 36 for suppressing the ISI-effect.

[0018] The first step in the receiver 24 is the filtering of the received signal 4 by the channel matched filter block 26, resulting in the filter signal 27. The filter signal 27 is fed to a correlator-bank 28 comprising M correla-

tors, wherein successive parts of the filter signal 27 are correlated with each of the M symbols from the predetermined set of symbols. This yields an output 29 of the correlator-bank 28 of M correlation values per part of the filter signal 27. The m^{th} correlation value results from the correlation between the part of the filter signal 27 and the m^{th} symbol from the predetermined set of symbols. Each of the correlation values is corrected by the correction block 30 with a correction value 31 in order to generate correlation values which are mutually comparable. In this example the correction value is half the energy of the corresponding symbol. The decision block 32 selects the symbol from the predetermined set of symbols which corresponds to the largest correlation value, this selected symbol is the detected symbol 6. Since the detection of the symbol is performed on symbol-by-symbol basis the ICI-effect is effectively suppressed (in an analogous way as described hereinbefore in relation to receiver 2). The suppression of the ISI-effect is suppressed with a feedback loop wherein the feedback block 34 generates a correction signal 36 on the basis of the detected symbol 6. (in an analogous way as described hereinbefore in relation to receiver 2).

[0019] It will be clear to those skilled in the art that the invention can be practised otherwise than as specifically illustrated and described without departing from its spirit or scope. For example, amplitude modulation can be used in combination with PSK-modulation.

Claims

1. A detection method using a receiver of a digital communication system for the detection of a symbol from a received signal, which signal is transmitted by a transmitter of the digital communication system, wherein the symbol is a selected symbol out of a predetermined set of symbols and wherein each symbol of the predetermined set comprises a sequence of chips wherein each of the chips is PSK-modulated according to a selected modulation code,

characterised in that,

a set of reference symbols is generated on the basis of the predetermined set of symbols and the channel impulse response between the transmitter and the receiver, wherein each of the successive parts of the received signal, each part having the length of a symbol, is compared with each of the reference symbols, yielding a detected symbol for each part of the received signal.

2. Method according to claim 1,
characterised in that,

a correction signal is generated on the basis of the detected symbol convolved with the channel impulse response, wherein the correction signal is subtracted from the part of the received signal

which succeeds the part of the received signal corresponding to the detected symbol for suppressing the ISI-effect.

5 3. Method according to one of the preceding claims,
characterised in that,
that the comparison between each of the parts of the received signal with each of the reference symbols is performed by a correlator yielding a correlation value, wherein the correlation value is corrected with half the energy of the reference symbol.

10 4. A detection method using a receiver of a digital communication system for the detection of a symbol from a received signal, which signal is transmitted by a transmitter of the digital communication system, wherein the symbol is a selected symbol out of a predetermined set of symbols and wherein each symbol of the predetermined set comprises a sequence of chips wherein each of the chips is PSK-modulated according to a selected modulation code,

characterised in that,

15 the received signal is filtered by a filter which yields a filter signal, wherein the filter is a matched filter to the channel impulse response between the transmitter and the receiver, wherein each of the successive parts of the filter signal, each part having the length of a symbol, is compared with each of the symbols from the predetermined set of symbols yielding a detected symbol for each part of the filter signal.

20 5. Method according to claim 4,
characterised in that,
a correction signal is generated on the basis of the detected symbol, wherein the correction signal is subtracted from the part of filter signal which succeeds the part of the filter signal corresponding to the detected symbol for suppressing the ISI-effect.

25 6. Method according to one of the claims 4-5,
characterised in that,
that the comparison, between each of the parts of the filter signal with each of the reference symbols, is performed by a correlator yielding a correlation value, wherein the correlation value is corrected with half the energy of the reference symbol.

30

35

40

45

50

55

FIG. 1

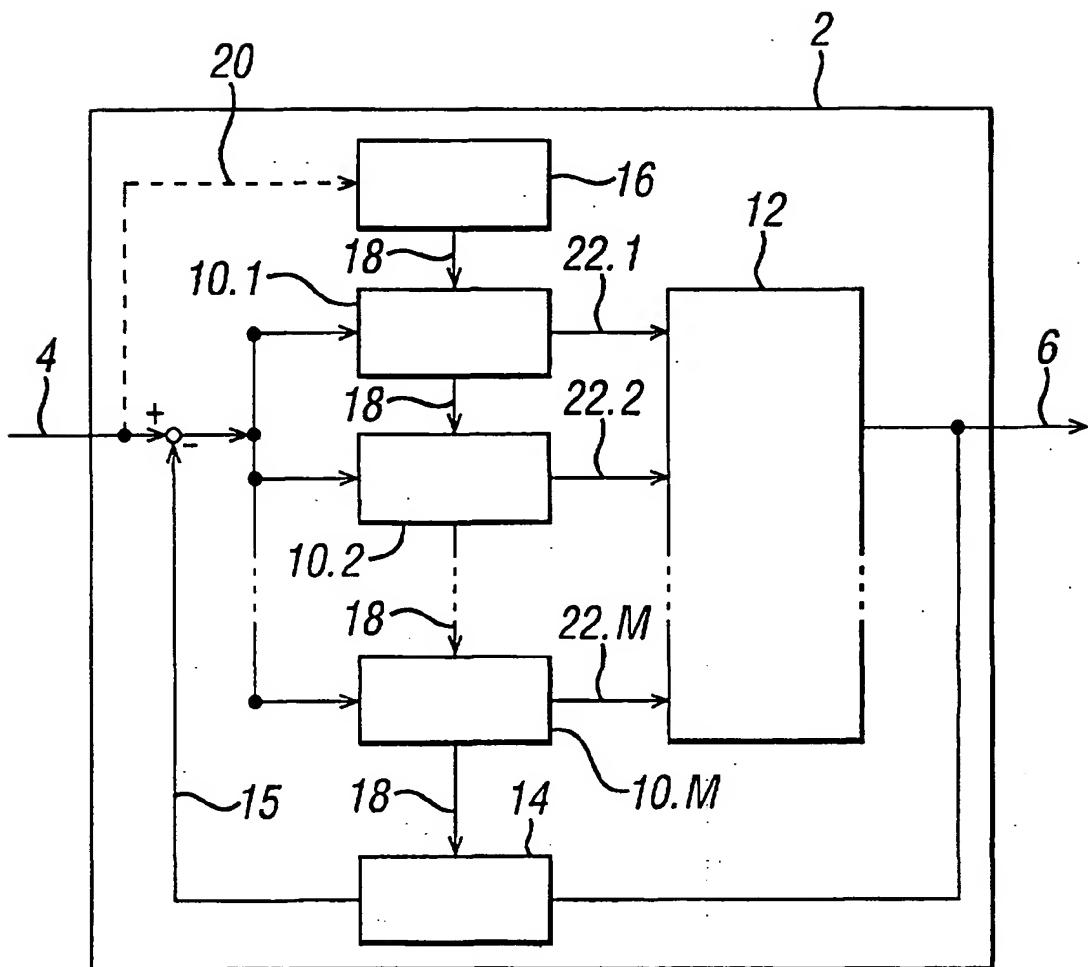


FIG. 2

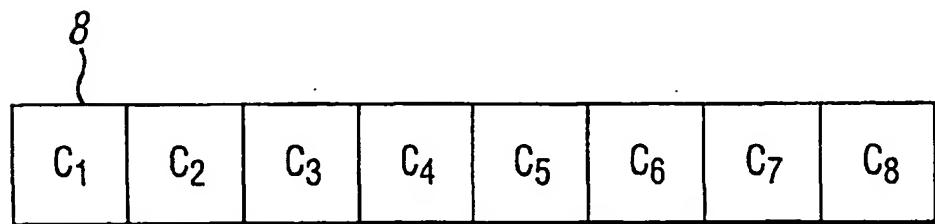
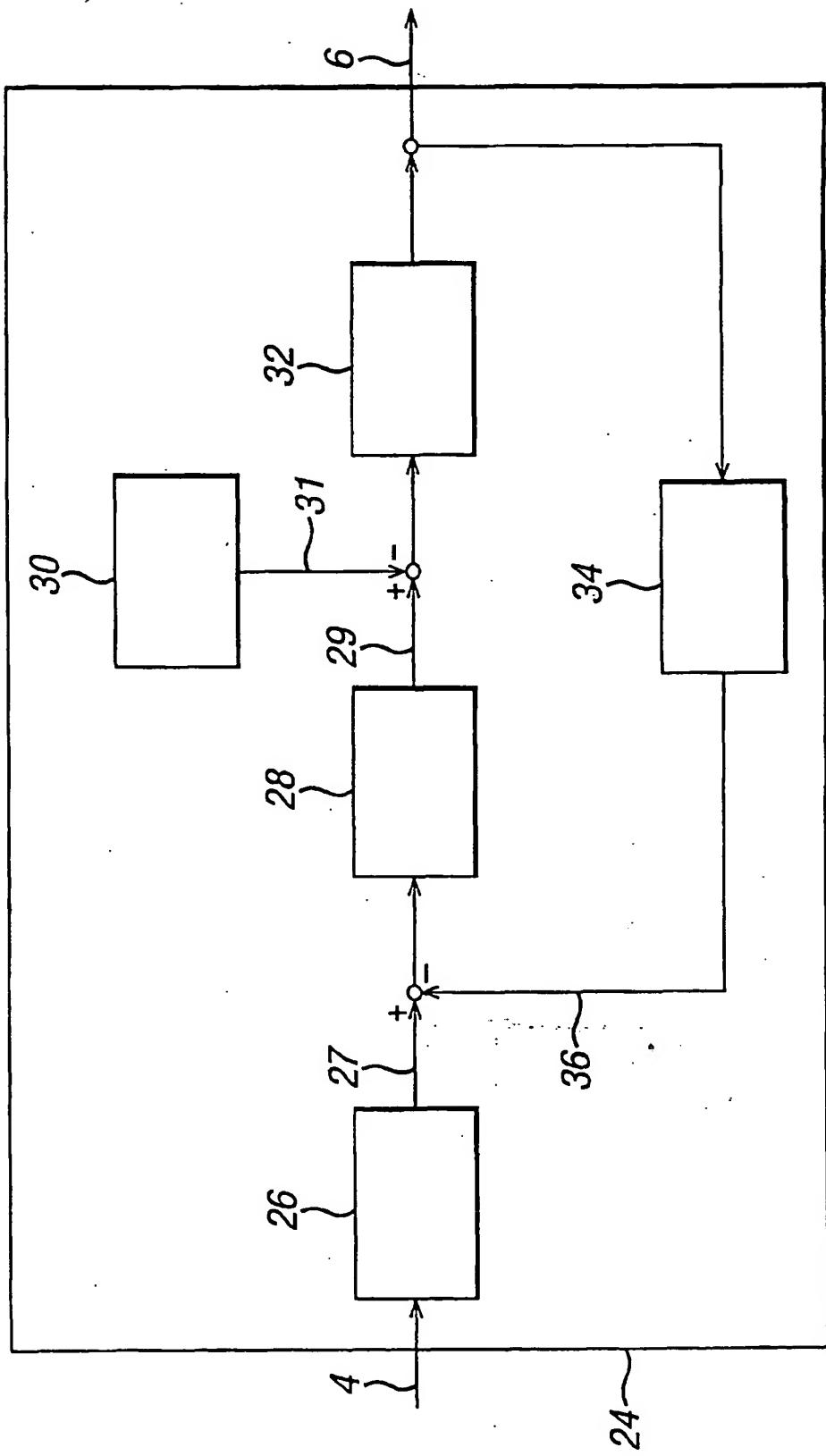


FIG. 3





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 0298

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	<p>WO 99 49586 A (ANDREN CARL ;HARRIS CORP (US); WEBSTER MARK A (US)) 30 September 1999 (1999-09-30) * abstract; claims 1,8,12,20; figures 1,25,35,42 * * page 17, line 9 - page 29 * * page 26, line 2 - line 24 *</p>	4-6	H04L25/03
A	<p>* page 28, line 26 - line 28 * * page 33, line 16 - line 29 * * page 36, line 3 - line 6 * * page 43, line 32 - page 44, line 5 * * page 51, line 34 - page 52, line 8 *</p>	1-3	
A	<p>EP 0 715 421 A (AT & T CORP) 5 June 1996 (1996-06-05) * abstract; claims 1,8; figures 2,6 * * page 8, line 36 - page 9, line 3 * * page 12, line 23 - line 27 * * page 12, line 55 - page 13, line 1 * * page 13, line 50 - line 57 * * page 14, line 23 - line 29 *</p>	1-6	
A	<p>HOU ET AL: "Complementary Filter Design for Testing of IS-95 Code Division Multiple Access Wireless Communication Systems" HOUSTON, TX, MAY 16 - 20, 1999, NEW YORK, NY: IEEE, US, vol. CONF. 49, 1999, pages 722-726, XP002158322 ISBN: 0-7803-5566-0 * abstract * * page 722, column 2, line 3 - line 19 * * page 724, column 2, line 14 - page 725, column 1, line 50 *</p>	3,6	<p>TECHNICAL FIELDS SEARCHED (Int.Cl.7)</p> <p>H04L</p>
<p>The present search report has been drawn up for all claims</p>			
Place of search	Date of completion of the search	Examiner	
BERLIN	8 May 2001	Masche, C	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 01 30 0298

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
 The members are as contained in the European Patent Office EDP file on
 The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

08-05-2001

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO 9949586 A	30-09-1999	AU	2456999 A	27-09-1999
		AU	2457099 A	27-09-1999
		AU	2652699 A	18-10-1999
		EP	1066691 A	10-01-2001
		EP	1072105 A	31-01-2001
		EP	1055290 A	29-11-2000
		WO	9946863 A	16-09-1999
		WO	9946887 A	16-09-1999
EP 0715421 A	05-06-1996	US	5623511 A	22-04-1997
		JP	8265297 A	11-10-1996